IS 8468 (1977): On-load tap changers [ETD 16: Transformers]

BLANK PAGE

Indian Standard
SPECIFICATION FOR ON-LOAD TAP-CHANGERS

(Fifth Reprint JULY 1999)

UDC 621.314.214.332

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 7

January 1978

AMENDMENT NO. 1 MAY 1980
TO
IS : 8468 - 1977 SPECIFICATION FOR ON-LOAD TAP-CHANGERS

Corrigenda

(*Page* 10, *clause* 8.4, *line* 3) — Substitute 'live' *for* 'line'.

[*Page* 12, *clause* 8.6.1.2(b), *line* 7] — Substitute 'manufacturer' *for* 'mnufacturer'.

(*Page* 18, *clause* 8.10.7, *heading*) — Substitute '*Lightning*' for '*Lighting*'.

Alterations

(*Page* 9, *clause* 8.2(c)] — Delete.

(*Page* 10, *clause* 8.5, *para* 1) — Substitute the following for the existing para:

'Tests shall be performed to verify that the temperature rise above oil of each type of contact which carries current continuously in service does not exceed 20°C, when the contacts have reached a steady temperature after carrying the maximum rated through current.'

[*Page* 10, *Table* 1)] — Delete.

(*Page* 17, *Table* 4, *col* 1, *entry* 8) — Substitute '140' *for* '149'.

(*Pages* 18 *and* 19, *clause* 9.2) — Substitute the following for the existing clause:

'**9.2 Permissible Variation of Auxiliary Supply** — The auxiliary supply for the driving motor shall be 415V (+ 10 percent, — 15 percent), 3-phase, 4-wire, 50Hz and for the electrical of motor drive mechanism 110V (+ 10 percent, — 15 percent) 1-phase, 50Hz unless otherwise specified by the purchaser.'

[*Page* 20, *clause* 10.1(h)] — Delete.

(*Page* 30, *clause* C-3, *formula*) — Substitute the following for the existing formula:

$$I_p = \frac{1}{\sqrt{k}} \sqrt{\frac{\sum_{i=1}^{n} (I^2_i \cdot t_i)}{\sum_{i=1}^{n} t_i}}$$

Addendum

[*Page* 9, *clause* 7.1(h)] — Add the following new item after 7.1(h):

'j) Direction of flow of power.'

(ETDC 16)

Printed at Printograph, New Delhi, Ph . 5726847

Indian Standard
SPECIFICATION FOR ON-LOAD TAP-CHANGERS

Transformers Sectional Committee, ETDC 16

Chairman

SHRI U. K. PATWARDHAN
Prayog Electricals Pvt. Ltd, Bombay

Members	*Representing*
SHRI S. AMMEERJAN	Bharat Heavy Electricals Ltd (R & D) Unit, Bhopal
SHRI N. S. S. AROKIASWAMY	Tamil Nadu Electricity Board, Madras
SHRI M. K. SUNDARARAJAN (*Alternate*)	
SHRI B. G. BHAKEY	Kirloskar Electric Co Ltd, Bangalore
DR B. N. JAYARAM (*Alternate*)	
SHRI A. V. BHEEMARAO	Gujarat Electricity Board, Vadodara
SHRI J. S. IYER (*Alternate*)	
SHRI S. D. CHOTRANEY	Bombay Electric Supply and Transport Undertaking, Bombay
SHRI Y. K. PALVANKAR (*Alternate*)	
DIRECTOR (TRANSMISSION)	Central Electricity Authority, New Delhi
[DEPUTY DIRECTOR (TRANSMISSION)] (*Alternate*)	
SHRI T. K. GHOSE	Calcutta Electric Supply Corporation Ltd, Calcutta
SHRI P. K. BHATTACHARJEE (*Alternate*)	
JOINT DIRECTOR (SUB-STATION)	Research, Designs and Standards Organization (Ministry of Railways), Lucknow
DEPUTY DIRECTOR STANDARDS (ELECTRICAL) (*Alternate*)	
SHRI J. K. KHANNA	Directorate General of Supplies and Disposals (Inspection Wing), New Delhi
SHRI K. L. GARG (*Alternate*)	
SHRI B. S. KOCHAR	Rural Electrification Corporation Ltd, New Delhi
SHRI R. D. JAIN (*Alternate*)	
SHRI J. R. MAHAJAN	Indian Electrical Manufacturer's Association, Bombay
SHRI P. K. PHILIP (*Alternate*)	
SHRI D. B. MEHTA	Tata Hydro-Electric Power Supply Co Ltd, Bombay
SHRI R. CHANDRAMOULI (*Alternate*)	
SHRI D. V. NARKE	Bharat Heavy Electricals Ltd, Bhopal
SHRI ISHWAR CHANDRA (*Alternate* I)	
SHRI PREM CHAND (*Alternate* II)	
SHRI I. S. PATEL	Hindustan Brown Boveri Ltd, Bombay
SHRI V. N. PRAHLAD	National Electrical Industries Ltd, Bombay
SHRI A. G. GURJAR (*Alternate*)	

(*Continued on page* 2)

(*Continued from page* 1)

Members	*Representing*
Shri K. N. Ramaswamy	Directorate General of Technical Development, New Delhi
Shri S. K. Palhan (*Alternate*)	
Shri Chandra K. Rohatgi	Pradip Lamp Works, Patna
Shri D. P. Sahgal	Siemens India Ltd, Bombay
Shri A. R. Salvi (*Alternate*)	
Shri I. C. Sangar	Delhi Electric Supply Undertaking, New Delhi
Shri R. C. Khanna (*Alternate*)	
Shri K. G. Shanmukhappa	NGEF Ltd, Bangalore
Shri P. S. Raman (*Alternate*)	
Shri M. A. Shariff	Karnataka Electricity Board, Bangalore
Shri B. C. Alva (*Alternate*)	
Superintending Engineer (Operation)	Andhra Pradesh State Electricity Department, (Electricity Projects and Board), Hyderabad
Superintending Engineer Technical (Projects) (*Alternate*)	
Shri C. R. Varier	Crompton Greaves Ltd, Bombay
Shri S. V. Manerikar (*Alternate*)	
Shri T. Rajaraman, Deputy Director (Elec tech)	Director General, ISI (*Ex-officio Member*)

Secretary

Shri Vijai
Deputy Director (Elec tech), ISI

Panel for On-Load Tap Changers, ETDC 16 : P5

Convener	
Shri D. V. Narke	Bharat Heavy Electricals Ltd, Bhopal
Members	
Shri S. C. Agarwal (*Alternate* to Shri D. V. Narke)	
Shri R. C. Chandramouli	Tata Hydro-Electric Power Supply Co Ltd, Bombay
Shri S. V. Manerikar	Crompton Greaves Ltd, Bombay
Shri V. N. Prahlad	National Electrical Industries Ltd, Bombay
Shri A. G. Gurjar (*Alternate*)	
Shri C. S. N. Raju	NGEF Ltd, Bangalore

Indian Standard
SPECIFICATION FOR ON-LOAD TAP-CHANGERS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 26 May 1977, after the draft finalized by the Transformers Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard is based on IEC Doc: 14B (Central Office) 10, revision of Publication 214 (1965) 'On-load tap-changers', issued by the International Electrotechnical Commission.

0.3 For selecting an on-load tap-changer for a particular application reference should be made to IS: 8478-1977*.

0.4 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test shall be rounded off in accordance with IS: 2-1960†. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

SECTION I GENERAL

1. SCOPE

1.1 This standard covers on-load tap-changers for power transformers, and their motor-drive mechanisms. It relates mainly to oil-immersed tap-changers.

1.2 Tap-changers for transformers for railway rolling stock are not covered by this standard.

NOTE 1 — As this standard deals only with on-load tap-changers the expression is shortened to 'tap-changer' in the remainder of this standard.

NOTE 2 — For the purpose of this standard a synthetic insulating liquid, for example, askarel is regarded as an oil.

2. DEFINITIONS

2.0 For the purpose of this standard, the following definitions shall apply.

---

*Application guide for on-load tap-changers.
†Rules for rounding off numerical values (*revised*).

2.1 Definitions Relating to On-Load Tap-Changers (Excluding Motor-Drive Mechanisms)

2.1.1 *On-Load Tap-Changer* — A device for changing the tapping connections of a winding, suitable for operation whilst the transformer is energised and is on-load. Generally, it consists of a diverter switch (**2.1.3**) with a transition impedance (**2.1.6**) and a tap selector (**2.1.2**) which can be with or without a change-over selector (**2.1.5**), the whole being operated by the driving mechanism (**2.1.7**). In some forms of tap-changers, the functions of the diverter switch and the tap selector are combined in a selector switch.

2.1.2 *Tap Selector* — A device designed to carry, but not to make or break current, used in conjunction with a diverter switch to select tapping connections.

2.1.3 *Diverter Switch* — A switching device used in conjunction with a tap selector to carry, make and break currents in circuits which have already been selected.

NOTE — Diverter switches of spring-operated type include an independent means of storing energy for their operation.

2.1.4 *Selector Switch* — A switching device capable of making, carrying and breaking current, combining the duties of a tap selector and a diverter switch.

2.1.5 *Change-Over Selector* — A device designed to carry, but not to make or break current, used in conjunction with a tap selector or selector switch to enable its contacts and the connected tappings, to be used more than once when moving from one extreme position to the other.

2.1.6 *Transition Impedance* — A resistor or reactor consisting of one or more units bridging the tapping in use and the tapping next to be used, for the purpose of transferring load from one tapping to the other without interruption or appreciable change in the load current, at the same time limiting the circulating current for the period that both tappings are used.

2.1.7 *Driving Mechanism* — The means by which the drive to the tap-changer is actuated.

NOTE — The mechanism may include an independent means of storing energy to control the operation.

2.1.8 *Set of Contacts* — A pair, or combination of pairs, of individual fixed and moving contacts, operating substantially simultaneously.

2.1.9 *Main Contacts and Main Switching Contacts of Diverter Switch or Selector Switch*

2.1.9.1 *Main contacts* — Any set of through-current carrying contacts which has no transition impedance between the transformer winding and the contacts and which does not switch any current.

2.1.9.2 *Main switching contacts* — Any set of contacts which has no transition impedance between the transformer winding and the contacts and which breaks the current.

2.1.10 *Transition Contacts* — Any set of contacts where a transition impedance is in series between the transformer winding and the contacts.

NOTE — In the case of reactor transition tap-changers this set of contacts is used, in many instances, to carry the through-current in the full tap-position.

2.1.11 *Circulating Current* — That part of the current which flows through the transition impedance at the time when two tappings are bridged during a tap-change operation and which is due to the voltage difference between the tappings.

2.1.12 *Switched Current* — The prospective current to be broken during switching operation by each set of main switching or transition contacts incorporated in the diverter switch or selector switch.

2.1.13 *Recovery Voltage* — The power frequency voltage which appears across each set of main switching or transition contacts of the diverter switch or selector switch after these contacts have broken the switched current.

2.1.14 *Tap-Change Operation* — A complete sequence of events from the initiation to the completion of one tap-change.

2.1.15 *Cycle of Operation* — The movement of the tap-changer from one end of its range to the other and the return to its original position.

2.1.16 *Insulation Level* — The withstand values of the impulse and power frequency test voltages to earth, and where appropriate between the phases and between those parts where insulation is required.

2.1.17 *Rated Through-Current* (I_u) — The current flowing through the tap-changer towards the external circuit, which the apparatus is capable of transferring from one tapping to the other at the relevant rated step voltage and which can be carried continuously while meeting the requirements of this standard.

NOTE — As to the relationship between a rated through-current and relevant step voltage, *see* **5.2**.

2.1.18 *Maximum Rated Through-Current* (I_{um}) — The rated through-current for which both the temperature rise of the contacts (**8.5**) and the service duty test (**8.6.1**) apply.

2.1.19 *Rated Step Voltage* (U_i) — For each value of rated through-current, the highest permissible voltage between terminals which are intended to be connected to successive tappings of a transformer.

NOTE — If a rated step voltage is given in connection with a rated through-current, it is called 'relevant rated step voltage'.

2.1.20 *Maximum Rated Step Voltage* (U_{im}) — The highest value of the rated step voltage for which the tap-changer is designed.

2.1.21 *Rated Frequency* — The frequency of the alternating current for which the tap-changer is designed.

2.1.22 *Number of Tap Positions of the Tap-Changer*

2.1.22.1 *Number of inherent tap positions* — The highest number of tap

positions for half a cycle of operation for which a tap-changer can be used according to its design.

2.1.22.2 *Number of service positions* — The number of tap positions for half a cycle of operation for which a tap-changer is used in a transformer.

NOTE — Terms defined in **2.1.22.1** and **2.1.22.2** are generally given as the ±values of the relevant numbers, for example, ±11 positions; they are principally valid also for the motor-drive mechanism.

When using the term 'Number of tap positions' in connection with a transformer, this always refers to the number of service tap positions of the tap-changer.

2.1.22.3 *Run-through tap* — The taps of the tap-changer connected to the tap winding of the transformer, but the tap-changer when electrically operated through these taps continues to run to the next tap without stopping at these particular taps.

2.1.23 *Type Test* — A test made on a tap-changer or the components of a tap-changer, or a range of tap-changers or components all based on the same design, to prove compliance with the standard.

NOTE — A range of tap-changers is a number of tap-changers based on the same design and having the same characteristics, with the exception of the insulation levels to earth and possibly between phases, the number of steps and the value of the transition impedance.

2.1.24 *Routine Test* — A test made on each finished tap-changer, the design of which has been verified by type tests, to establish that the tap-changer is without manufacturing defects.

2.2 Definitions Relating to Motor-Drive Mechanisms

2.2.1 *Motor-Drive Mechanism* — A driving mechanisms (*see* **2.1.7**), which incorporates an electrical motor and control circuit.

2.2.2 *Step-by-Step Control* — Electrical and mechanical devices stopping the motor-drive mechanism after completion of one tap-change independently of the operating sequence of the control switch.

2.2.3 *Tap Position Indicator* — Electrical and/or mechanical devices for indicating the tap position of the tap-changer.

2.2.4 *Tap-Change in Progress Indication* — A device indicating that the motor-drive mechanism is running.

2.2.5 *Limiting Devices*

2.2.5.1 *Limit switches* — Electro-mechanical devices preventing operation of the tap-changer beyond either end position but allowing operation towards the opposite direction.

2.2.5.2 *Mechanical end stop* — A device which physically prevents operation of the tap-changer beyond either end position but allows operation towards the opposite direction.

2.2.6 *Parallel Control Devices* — Electrical control devices to move, in the case of parallel operation of several transformers with tappings, all tap-

changers to the required position and to avoid divergence of the respective motor-drive mechanisms.

NOTE — Such devices would be necessary also in the case of single-phase transformers forming a three-phase bank when each single-phase tap-changer is fitted with its own motor-drive mechanism.

2.2.7 *Emergency Tripping Device* — An electrical and/or mechanical device for stopping the motor-drive mechanism at any time in such a way that a special action should be performed before the next tap-change operation can be started.

2.2.8 *Overcurrent Blocking Device* — An electrical device preventing or interrupting operation of the motor-drive mechanism for the period in which an overcurrent exceeding a preset value is flowing in the transformer winding. The blocking device may be in the form of a contactor in the motor-drive mechanism.

2.2.9 *Operation Counter Mechanism* — A device indicating the number of tap-changes accomplished.

2.2.10 *Manual Operation of Tap-Changer* — Operation of the tap-changer manually by a mechanical device, blocking at the same time operation by the electrical motor.

2.2.11 *Motor-Drive Cubicle* — A cubicle housing the motor-drive mechanism.

3. SERVICE CONDITIONS

3.1 Temperature of Tap-Changer Environment — Unless more onerous conditions are specified by the purchaser, on-load tap-changers shall be regarded as suitable for operation over a temperature range of −5 to 100°C when the cooling medium is oil.

NOTE — The value of 100°C quoted above is based on a maximum ambient temperature of 50°C as specified in IS: 2026(Part I)-1977*.

3.2 Temperature of Motor-Drive Mechanism Environment — Unless more onerous conditions are specified by the purchaser, motor-drive mechanisms are regarded as being suitable for operation in any ambient temperature between −5°C and 50°C.

3.3 Overload Conditions — Tap-changers subjected to overload conditions in accordance with IS : 6600-1972† shall generally be restricted to the occasional overload conditions stated in IS : 2026 (Part I)-1977* if not specifically ordered for other overload conditions by the transformer manufacturer (*see* IS : 8478 - 1977‡).

NOTE — Tap-changers, like other switching devices, usually have a shorter thermal time constant than electromagnetic devices of the same current ratings.

*Specification for power transformers: Part I General (*first revision*).
†Guide for loading of oil-immersed transformers.
‡Application guide for on-load tap-changers.

4. INFORMATION REQUIRED WITH TENDER AND ORDER

4.1 The technical information that the purchaser is required to supply with the tenders and orders is given in IS : 8478 - 1977*.

SECTION 2 ON-LOAD TAP-CHANGERS (EXCLUDING REQUIREMENTS FOR MOTOR-DRIVE MECHANISMS)

5. RATING

5.1 Rated Characteristics — The characteristics of a tap-changer that shall be used to determine the rating are as given in **5.2** to **5.6**.

5.2 Rated Through-Current — The rated through-current is inter-related with a relevant rated step voltage. Therefore a tap-changer may have different combinations of rated through-current and relevant rated step voltage.

5.3 Maximum Rated Through-Current — Preferred values of maximum rated through-current, shall be:

100, 200, 400, 800, 1 250, 1 600, 2 000, 2 500 and 3 150 A.

Adoption of other values does not invalidate compliance with this standard.

5.4 Rated Step Voltage — This shall be stipulated by the purchaser.

5.5 Rated Frequency — The rated frequency shall be 50 Hz.

5.6 Rated Insulation Level — This shall be stipulated by the purchaser.

6. DESIGN AND CONSTRUCTION

6.1 Limiting Devices for the Protection of Tap-Changers Against Transient Voltages — For tap-changers which incorporate limiting devices for transient voltages, the manufacturer of the tap-changer shall give full details of the protective characteristics, together with any limitations which shall be imposed during tests on the completed transformer.

When spark gaps are used, care has to be taken to ensure that after spark-over, the discharge is quenched automatically.

6.2 Oil Level Gauges — If diverter or selector switches are located in separate oil containers breathing freely to the atmosphere, oil level gauges shall be provided.

6.3 Suitable protective devices may be provided in the tap-changer.

*Application guide for on-load tap-changers.

7. MARKING

7.1 Each tap-changer shall be provided with a name-plate of weather-proof material fitted in a visible position showing at least the items indicated below. The entries shall be indelibly marked (for example by etching, engraving or stamping).

a) Number of this standard, Ref: IS : 8468,
b) Manufacturer's name,
c) Manufacturer's serial number,
d) Manufacturer's type designation,
e) Year of manufacture,
f) Rated through-current,
g) Rated step voltage, and
h) Rated insulation level.

7.1.1 The tap-changers may also be marked with the ISI Certification Mark.

NOTE — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act and the Rules and Regulations made thereunder. The ISI Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by ISI and operated by the producer. ISI marked products are also continuously checked by ISI for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the ISI Certification Mark may be granted to manufacturers or processors, may be obtained from the Indian Standards Institution.

8. TESTS

8.1 Type Tests — The type tests shall be performed on the samples of the relevant tap-changer or components after their final development. The following shall constitute the type tests:

a) Mechanical test (8.3),
b) Auxiliary circuits insulation tests (8.4),
c) Test for temperature-rise of contacts (8.5),
d) Switching tests (8.6),
e) Short circuit current test (8.7),
f) Transition impedance test (8.8),
g) Mechanical life test (8.9), and
h) Dielectric test (8.10).

8.2 Routine Tests — The following shall constitute the routine tests:

a) Mechanical test (8.3),
b) Auxiliary circuits insulation tests (8.4), and
c) Dielectric tests [8.10.3(a) and 8.10.3(d) only.]

NOTE — Attention is drawn to the tests to be carried out on tap-changers after assembly on transformers specified in IS: 2026(Part I)-1977*.

*Specification for power transformers: Part I General (*first revision*).

8.3 Mechanical Test — With the tap-changer fully assembled, but without the contacts energized, ten complete cycles of operation shall be performed without failure.

8.4 Auxiliary Circuits Insulation Test — The tap-changer auxiliary circuits shall withstand without failure a power-frequency test voltage of 2 kV applied for one minute between all line terminals and the frame.

8.5 Test for Temperature-Rise of Contacts — Tests shall be performed to verify that the temperature rise above the medium surrounding each type of contact which carries current continuously in service does not exceed the values given in Table 1, when the contacts have reached a steady temperature after carrying the maximum rated through-current.

TABLE 1 CONTACT TEMPERATURE RISE-LIMITS

CONTACT MATERIAL	IN OIL
(1)	(2)
	°C
Plain copper	20
Silver-faced copper	20
Other materials	20

The temperatures shall be measured by thermocouples or other suitable means positioned on the surface of the contacts as near the point of contact as is practicable.

The temperature is considered to be steady when the difference of the temperature between the contact and the surrounding medium does not change by more than 1°C over the last quarter of the test period.

The temperature of the surrounding medium shall be measured at not less than 25 mm below the contacts.

NOTE — The cross-section of the conductor carrying the current into the tap-changer or components under test shall be stated.

8.6 Switching Tests — Switching tests, which include service duty tests and breaking capacity tests, shall simulate the most onerous conditions for which the tap-changer is rated. Where reactor switching is concerned, the most onerous condition shall be subject to agreement between the manufacturer and the purchaser. Unless otherwise agreed, it is assumed that no reversal of power flow occurs in service.

Attention is drawn to Appendix A where the most onerous conditions for resistor transition switching are indicated for the majority of contact arrangements.

The switching tests may be limited to the diverter switch or selector switch after proving that the contact operating conditions are not affected by such limitation.

If the diverter switch or selector switch has several sets of contacts which operate in a definite sequence, it is not permitted to test each set of contact separately from the other unless it can be proved that the operating conditions of any one set of contacts are not affected by the operation of the other sets of contacts.

Where resistors are used as transition impedances these may be placed outside the apparatus if necessitated by the construction of the tap-changer or the test circuit, and they may have a higher thermal capacity than those which are employed in service unless otherwise specified.

The value and type of the transition impedance shall be stated.

Contacts, and transformer oil in the case of oil-immersed tap-changers, shall not be renewed during each of the tests.

In the case of three-phase switches, it is normally sufficient to test the contacts of one phase.

If a particular tap-changer has more than one combination of rated through-current and rated step voltage at least two braking capacity tests shall be performed, one at maximum rated through-current I_m and its relevant step voltage U_1 and one at the maximum rated step voltage U_m and its relevant rated through-current I_u.

Interpolation may be facilitated by obtaining the mid-current point of the curve between the extremes by calculating this mid-point X as:

$$\left(\frac{I_m+I_u}{2}\right)(U_x)=\sqrt{U_1 I_m \times U_m I_u}$$

The arrangement for testing shall be such that, except where otherwise specified, neither the switched current, nor the recovery voltage, nor the product of these shall, in any case, vary more than -5 percent to $+10$ percent of the calculated values appropriate to the switching cycle (*see* Table 5) at the appropriate through-current and relevant rated step voltage.

8.6.1 *Service Duty Test* — This test shall be performed in accordance with **8.6.1.1**, **8.6.1.2** or **8.6.1.3**.

After the tests, inspection of contact wear shall be done, the results of this test shall leave no doubts as to the suitability of the tap hanger for service.

NOTE — The results of this test may be used by the manufacturer to demonstrate that the contacts used for making and breaking current are capable of performing, without replacement of the contacts, the number of tap-change operations declared by the manufacturer at the rated through-current and at the relevant step voltage.

8.6.1.1 *Service duty test at rated step voltage* — The contacts on diverter switches and selector switches shall be subjected to a number of operations corresponding to 20 000 tap-change operations in normal service when carrying a current corresponding to not less than the maximum rated through-current and the relevant rated step voltage.

In order to approximate to service conditions, selector switches shall have the test performed over not more than eight tap-change positions (excluding dead positions), these being centrally disposed about the change-over selector if such is incorporated in the tap-changer design.

Comparison of oscillograms taken at regular intervals during the test shall show that there is no significant alteration in the characteristics of the tap-changer in such a way as to endanger the operation of the apparatus. Twenty oscillograms shall be taken at the start of the test, and 20 after each succeeding 5 000 operations, making a total of 100 oscillograms.

NOTE — Generally it is sufficient to compare the series of oscillograms taken at the beginning and at the end of the test.

8.6.1.2 *Service duty test at reduced step voltage* — Provided that the manufacturer supplies reasonable proof that the rate of wear is not affected, a test at reduced step voltage may be performed under the following conditions:

a) A service duty test of 20 000 operations shall be performed at a current corresponding to not less than the maximum rated through-current and a reduced step voltage. This voltage level shall be such that the switched current is not less than that occurring during operations at the relevant rated step voltage; furthermore, current chopping shall not occur. In order to obtain the specified test conditions, the value of the transition impedance shall be suitably modified.

b) Using the same contacts and oil, 100 operations at the maximum rated through-current and the relevant rated step voltage shall be performed, each operation being oscillographically recorded. Provided the oscillograms taken during these operations indicate that the arcing time does not exceed $\frac{1.2}{2f}$ second (where f is the rated frequency) this service duty test with the calculated switched current and reduced step voltage will enable the manufacturer to demonstrate directly the number of operations likely to be achieved without replacement of contacts.

c) When the oscillograms indicate that arcing times in excess of $\frac{1.2}{2f}$ seconds are occurring then further operations shall be performed at the maximum rated through-current and the reduced step voltage. The number of such additional operations shall be:

$$\frac{2S}{100} \times 20\,000$$

where S = total number of half-cycles of arcing current, in the 100 operations from (b) above, which occur after the first current zero following contact separation.

d) Comparison of the oscillograms taken under (b) above with those taken under similar conditions with new contacts and clean transformer oil shall show whether there has been any significant alteration in the characteristics of the tap-changer such as might endanger the operation of the apparatus.

The test sequence specified above is designed to give substantially the same contact erosion as would occur during 20 000 operations at maximum rated through-current and the relevant rated step voltage.

8.6.1.3 *Service duty test for selector switches* — The tests may be performed as in 8.6.1.1 or 8.6.1.2.

When selector switches are designed for asymmetrical pennant cycle switching, owing to the load and circulating currents together with their associated recovery voltages being vectorially subtractive, the most onerous switching duties for the main contact occur at full-load and at no-load (*see* Table 5).

In service the majority of transformers do not normally operate at full-load and, in consequence, there is always arc-erosion in the subtractive condition. Therefore in order to approximate more nearly to service conditions the test shall be performed with 10 000 operations at full-load parameters and 10 000 operations at no-load parameters.

8.6.2 *Breaking Capacity Test* — Forty operations shall be performed at a current corresponding to twice the maximum rated through-current and at the relevant rated step voltage.

The oscillograms taken for each operation shall indicate that in no case is the arcing time such as to endanger the operation of the apparatus.

The breaking capacity test shall be performed, if possible, with a transition impedance of the same thermal and ohmic design as that to be employed in service. If this is not possible the impedance as used in service shall be tested separately in accordance with 8.8.1 but with twice maximum rated through-current for one operation only.

8.6.3 *Simulated Test Circuits* — The tests under 8.6.1.1, 8.6.1.2 and 8.6.1.3 may be performed with simulated circuits providing it is proved that the test conditions are substantially equivalent. Two simulated test circuits which are possible for use are described in Appendix B.

8.7 Short-Circuit Current Test — All contacts of different design carrying current continuously shall be subjected to short-circuit currents, each of two seconds (±10 percent) duration. In the case of oil-immersed tap-changers the test shall be performed in transformer oil.

In the case of three-phase tap-changers it is sufficient to test the contacts of one phase only unless otherwise specified.

Three applications shall be made with an initial peak current of 2·5 (±5 percent) times the symmetrical rms value of the short-circuit test current.

When there are no facilities for point-on-wave switching and it is not possible to obtain three short-circuit applications with an initial peak current of 2·5 times the rms value, the following test may be used:

> The symmetrical value of the short-circuit test current may be increased so that the peak current is obtained for the three applications and the test duration reduced. When using this method the product of the square of the increased rms current and the shorter test duration shall not be less than the product of the square of the rated short-circuit rms current and the 2 seconds duration.

The values of the short-circuit test current to be applied shall be as specified in Table 2.

NOTE — If the short-circuit requirements of the transformer exceed that given in Table 2 for the maximum rated through-current of the tap-changer, unless otherwise agreed between the manufacturer and the purchaser, a tap-changer of the appropriate higher maximum rated through-current shall be adopted.

TABLE 2 SHORT-CIRCUIT TEST CURRENT

MAXIMUM RATED THROUGH CURRENT	TEST CURRENT RMS VALUE
(1)	(2)
A	kA
100	2
200	3
400	4
800	8
1 250	12·5
1 600	16
2 000	20
2 500	25
3 150	31·5

For intermediate values of maximum rated through-current up to 400 A, the test current may be interpolated from the above table. For values above 400 A, the test current shall be 10 times the maximum rated through-current.

The open-circuit voltage for the test shall be at least 50 V.

At the conclusion of the test, the contacts shall not have welded together and shall not show abnormal signs of current marking or burning.

Current-carrying parts shall not show signs of permanent mechanical distortion.

8.8 Transition Impedance Test

8.8.1 *Transition Resistors* — The test shall be performed at the maximum rated through-current and at the relevant rated step voltage.

The resistor shall be mounted as in service or separately under equivalent thermal conditions.

The resistor shall be subjected to a number of power-impulses equivalent to one-half of one cycle of uninterrupted operation (*see* **2.1.15**) with the driving mechanism operating at its normal speed. The final temperature of the resistor shall be determined and recorded.

The temperature rise above the surrounding medium shall not exceed 200°C for oil-immersed tap-changers.

If it is not practicable to determine the temperature of the transition resistor according to the above then the method given in Appendix C may be employed.

NOTE — In cases where the rated through-current or the relevant rated step voltage is different from the maximum rated through-current and the relevant rated step voltage, it is permissible to calculate the thermal rating of the resistor from the results of the type test.

8.8.2 *Transition Reactors* — Transition reactors are normally tested in accordance with the specification for the transformer with which the tap-changer is intended for use.

NOTE — Precautions should be taken in the design of the transition reactors to avoid high inrush currents during switching.

8.9 Mechanical Life Tests

8.9.1 *Mechanical Endurance Test* — If the tap-changer is of oil-immersed design it shall be assembled and filled with clean transformer oil, or immersed in a test tank filled with clean transformer oil, and operated as for normal service conditions. The contacts shall not be energized and the full range of tappings shall be utilized until 200 000 tap-change operations have been performed.

During the test there shall be no failure or undue wear of the mechanical parts.

Normal servicing according to the manufacturer's handbook shall be permitted during the test.

It shall be permitted to perform this mechanical endurance test separately on diverter switches, selector switches, tap selectors or other components, provided that in each case the operation duplicates mechanically its normal service operation.

8.9.2 *Sequence Test* — With tap-changer assembled as in service, and if of oil-immersed design in clean transformer oil, it shall be operated over one complete cycle of operations. With the contacts energized at the voltage of the recording equipment the exact time sequence of operation of the tap selector, change-over selector, diverter switch or selector switch, as appropriate, shall be recorded.

8.9.3 *Pressure and Vacuum Tests* — If required, tests shall be performed to establish the pressure and vacuum withstand values on the compartments and bushings of the tap-changer. The manufacturer shall declare these values.

8.10 Dielectric Tests

8.10.1 *General* — The dielectric requirements of a tap-changer depend on the transformer winding to which it is to be connected.

The transformer manufacturer shall be responsible not only for selecting a tap-changer of the appropriate insultation level but also for the insulation level of the connecting leads between the tap-changer and the windings of the transformer.

Apparatus of oil-immersed design shall be filled with clean transformer oil or immersed in a test tank filled with clean transformer oil before the tests are performed.

8.10.2 *Classification* — To permit selection of appropriate voltage test tap-changers shall be classified according to Table 3.

TABLE 3 CLASSES OF TAP-CHANGERS

Class	Application
I	For use at the neutral point of windings
II	For use at a position other than the neutral point of windings

8.10.3 *Nature of Tests* — The insulation level of the tap-changer shall be proved by the following power-frequency and/or impulse voltage withstand tests:

a) To earth;
b) Between phases;
c) Between the first and last contacts of the tap selector or selector switch and, where fitted, of the change-over selector;
d) Between any two adjacent contacts of the tap-changer or selector switch or any other contacts relevant to the tap-changer contact configuration; and

e) Between diverter switch contacts in their final open position.

NOTE 1 — Regarding item (a) above, for Class I tap-changers, impulse voltage tests may not always be necessary. Their requirement shall be subject to agreement between the manufacturer and the purchaser.

NOTE 2 — Item (b) above does not apply to single-phase tap-changers.

NOTE 3 — Partial discharge measurements and switching impulse test are specified in IS: 2026(Part III)-1977* for transformers greater than 145 kV class. Consideration should be given to the application of the appropriate tests to earth and where applicable between phases of the tap-changer.

8.10.4 *Test Voltages*

8.10.4.1 *Class I* — For test **8.10.3** (a), the test voltage shall preferably comply with an appropriate value from Table 4. For the tests **8.10.3(b)** to **8.10.3**(e), appropriate withstand values shall be declared by the manufacturer of the tap-changer.

8.10.4.2 *Class II* — For tests **8.10.3**(a) and **8.10.3**(b) test voltages shall preferably comply with the appropriate values from Table 4. For tests **8.10.3**(c) to **8.10.3**(e), appropriate withstand values shall be declared by the manufacturer of the tap-changer.

TABLE 4 TEST VOLTAGE

(*Clauses* 8.10.4.1 and 8.10.4.2)

POWER-FREQUENCY TEST VOLTAGE (1) kV rms	LIGHTNING IMPULSE TEST VOLTAGE (2) kV peak
10	40
20	60
28	75
38	95
50	125
70	170
95	250
140	325
185	450
230	550
275	650
325	750
360	850
395	950
460	1 050

8.10.5 *Application of Test Voltages* — For the voltage tests, the tap-changer shall be assembled and dried out. It is not, however, necessary to include

*Specification for power transformers: Part III Insulation levels and dielectric test (*first revision*).

leads for connecting the tap-changer to the windings of a transformer. Tests may be performed on separate components provided it can be shown that same dielectric conditions apply.

For test **8.10.3**(a) and test **8.10.3**(b) in the case of Class II tap-changers the live parts of each phase shall be short-circuited and connected either to the voltage source or to earth as appropriate.

Where the tap-changer incorporates external insulation to earth, this external insulation shall be proved in accordance with the relevant test specified in IS : 2099-1973*.

8.10.6 *Power-Frequency Voltage Test* — The test shall be performed with a single-phase alternating voltage in accordance with IS : 2071 (Part I)-1974† and IS : 2071 (Part II)-1974‡ at the required value. The duration of each test application shall be 60 seconds.

8.10.7 *Lighting Impulse Voltage Test* — The wave for the test shall be the standard impulse of 1·2 ($\pm$30 percent) 50° ($\pm$20 percent) microseconds as defined in IS : 2071 (Part I)-1974† and IS : 2071 (Part III)-1974§. Each test shall comprise three voltage applications of positive polarity and three of negative polarity, at the required value.

8.10.8 *Measurement of Partial Discharges* — Under consideration (*see* **8.10.3**, Note 3).

8.10.9 *Switching Impulse Test* — Under consideration (*see* **8.10.3**, Note 3).

8.11 Type-Test Certificate — The certificate shall include the following:

a) Full details of the test arrangements adopted (for example, assembly arrangement and drying out) with explanatory sketches as necessary.

b) Full details of all tests applied in accordance with **8.3** to **8.10**.

c) Full details of limiting devices for transient voltages, where appropriate (*see* **6.1**).

SECTION 3 MOTOR-DRIVE MECHANISMS FOR ON-LOAD TAP-CHANGERS

9. DESIGN AND CONSTRUCTION

9.1 Unless otherwise specified, component parts of motor-drive mechanisms shall comply with relevant Indian Standards.

9.2 Permissible Variation to Auxiliary Supply — The driving motor and the electrical control of the motor-drive mechanism shall be designed to

*Specification for bushings for alternating voltages above 1 000 V (*first revision*).

†Methods of high voltage testing: Part I General definitions and test requirements (*first revision*).

‡Methods of high voltage testing: Part II Test procedures (*first revision*).

§Methods of high voltage testing: Part III Measuring devices.

operate satisfactorily within the limits of 85 to 110 percent of rated voltage for an ac voltage and between 80 and 110 percent for a dc voltage.

9.3 Step-by-Step Control — The step-by-step circuit shall be designed in such a way as to operate the tap-changer by one complete voltage step only in the case of signals which may be continuous or immediately repetitive as well as simultaneous from separate sources within one tap-change operation.

9.4 Tap Position Indicator

9.4.1 The position of the tap-changer shall be indicated on the motor-drive by means of a mechanically operated device. This tap position shall be visible through an inspection window while the motor-drive cubicle is closed.

9.4.2 If required, an electrical remote position transmitter may be provided for indicating the tap-changer position in the control room.

9.5 Tap-Change in Progress Indication — If required, a suitable device may be fitted to operate a means of indicating at a remote point that the motor-drive mechanism is performing a tap-change operation.

9.6 Limiting Devices — All motor-drive mechanisms shall be provided with both electrical and mechanical limiting devices. The contacts of the electrical limiting device shall be connected into the control or motor circuits.

9.7 Parallel Control Devices — Provision of the necessary devices is to be agreed, the purchaser being responsible for ensuring that the correct requirements are specified.

9.8 Direction of Rotation Protection — If required, a device for prevention of incorrect rotation of three-phase motors may be fitted by agreement between the manufacturer and the purchaser.

9.9 Overcurrent Blocking Device — If required by the operational condition of the transformer, this device may be fitted by agreement between the manufacturer and the purchaser.

9.10 Operation Counter — An operation counter shall be provided.

9.11 Manual Operation of the Motor-Drive Mechanism — A removable crank shall be provided for manual operation of the tap-changer, with blocking of the motor-drive taking place before actual engagement of the crank with the manual operating shaft.

The direction of rotation shall be provided adjacent to the hand crank engagement point and the number of crank rotations required for one tap-change operation shall be given.

NOTE — The design of the mechanism should permit manual operation by one man without undue effort. It can be assumed that this condition is satisfied if the maximum torque which has to be applied to crank handle does not exceed 50 Nm.

9.12 Motor-Drive Cubicle — The motor-drive cubicle shall meet with the protection requirements of IP 44 according to IS : 2147-1962* and shall be protected against condensation by suitable means.

If required, other degrees of protection specified in IS : 2147-1962* may be agreed between the manufacturer and the purchaser.

10. MARKING

10.1 Each motor-drive mechanism shall be provided with a name-plate of weather-proof material, fitted in a visible position showing the appropriate items indicated below. The entries shall be indelibly marked (for example by etching, engraving or stamping).

a) Number of this Indian Standard, Ref: IS : 8468;
b) Manufacturer's name;
c) Manufacturer's serial number and type;
d) Year of manufacture;
e) Rated voltage and rated frequency for the electrical motor (*see* Note);
f) Rated voltage and rated frequency for the control equipment (*see* Note);
g) Number of service tapping positions; and
h) Direction of flow of power.

NOTE — In the case of direct current supply, the symbol '—' should be used in place of the indication of the rated frequency.

11. TESTS

11.1 Type Tests — The following shall constitute the type tests:

a) Mechanical test (**11.3**),
b) Auxiliary circuits insulation test (**11.4**),
c) Mechanical load test (**11.5**),
d) Overrun test (**11.6**), and
e) Protection of motor-drive cubicle (**11.7**).

11.2 Routine Tests — The following shall constitute the routine tests:

a) Mechanical tests (**11.3**), and
b) Auxiliary circuits insulation tests (**11.4**).

11.3 Mechanical Tests

11.3.1 The motor-drive mechanism in the service condition or with an equivalent simulated load shall be operated electrically for ten cycles of operation without failure. During this test correct functioning to any requirements of **9**, where relevant, shall be checked.

*Degrees of protection provided by enclosures for low voltage switchgear and controlgear.

11.3.2 Following the test under **11.3.1**, two further cycles of operation shall be performed, one at the minimum and one at the maximum level of the rated voltage of the auxiliary supply, also without failure.

NOTE — The mechanical tests may be performed on the motor-drive mechanism separately or as under **8.9**.

11.4 Auxiliary Circuits Insulation Test — Auxiliary circuits, except the motor and such elements which are to be tested with lower test voltages according to the appropriate Indian Standards shall withstand a power-frequency test of 2 kV applied for one minute between all live terminals and the frame.

11.5 Mechanical Load Test — The motor-drive mechanism output shaft shall be loaded by the largest tap-changer for which it is designed or by an equivalent simulated load, based on service conditions. At such a load 200 000 operations shall be performed across the whole tapping range.

NOTE — Additional cooling of the motor-drive is permissible during this test.

During this test 5 000 operations shall be performed at the minimum voltage and 5 000 operations at the maximum voltage as specified in **9.2**.

The correct functioning to the requirements of **9.4.1**, **9.6**, **9.10** and **9.11** shall be verified during this test.

The test shall be completed without failure of the mechanical parts.

Normal servicing according to the manufacutrer's handbook shall be permitted during the test.

11.6 Overrun Test — It shall be demonstrated that in the event of a failure of the electrical limit switches, the mechanical end stops prevent operation beyond the end positions when a motorized tap-change is performed and the motor-drive mechanism shall not suffer either electrical or mechanical damage.

11.7 Protection of Motor-Drive Cubicle — When applicable, the motor-drive cubicle shall be tested in accordance with IS : 2147-1962*.

*Degrees of protection provided by enclosures for low voltage switchgear and controlgear

APPENDIX A

(*Clause* 8.6)

SUPPLEMENTARY INFORMATION ON SWITCHING DUTY RELATING TO TAP-CHANGERS WITH RESISTOR TRANSITION ONLY

A-1. ADDITIONAL DEFINITIONS

A-1.1 Flag-Cycle* — A method of performing a tap-change operation in which the through-current is diverted from the main contacts before the circulating current starts to flow.

NOTE — This cycle requires that the through-current connection is at the mid-point of the transition impedance when this is carrying the circulating current.

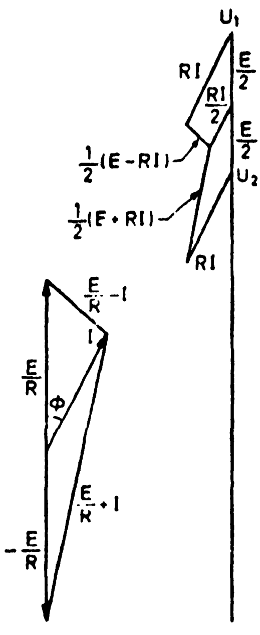


FIG. 1 FLAG CYCLE

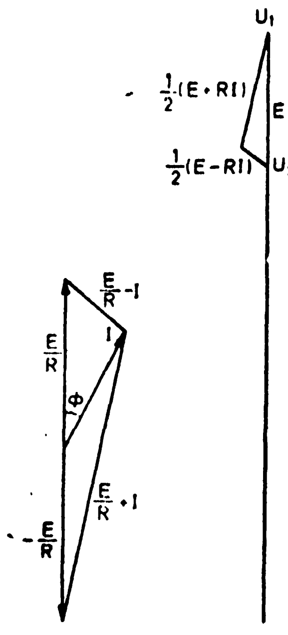


FIG. 2 SYMMETRICAL PENNANT CYCLE

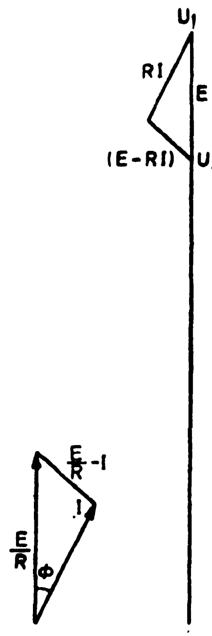


FIG. 3 ASYMMETRICAL PENNANT CYCLE

*The derivation of the designations 'flag cycle' and 'pennant cycle' arises from the appearance of the vector diagrams showing the change in output voltage of the transformer in moving from one tapping to the adjacent one. In the 'flag cycle' the change of voltage comprises four steps, while in the 'pennant cycle' only two steps occur (*see* Fig. 1 to 3).

A-1.2 Symmetrical Pennant Cycle* — A method of performing a tap-change operation in which the circulating current starts to flow before the through-current is diverted from the main contacts.

NOTE — This cycle requires that the through-current connection is at the mid-point of the transition impedance when this is carrying the circulating current.

A-1.3 Asymmetrical Pennant Cycle* — A method of performing a tap-change operation in which, in one direction of movement of the switch, the circulating current starts to flow before the through-current is diverted from the main contacts, while in the other direction of movement the through-current is diverted before the circulating current starts to flow.

NOTE 1 — This cycle requires that the through-current connection is at one end of the transition impedance when this is carrying circulating current.

NOTE 2 — Tap-changers employing the asymmetrical pennant cycle are normally used with load flow in one direction only.

A-2. DUTY ON MAIN AND TRANSITION CONTACTS

A-2.1 Table 5 shows typical contact arrangements used for flag and pennant cycles on diverter switches and selector switches. Only one pair of contacts is shown for each function although, in practice, this may represent a set of contacts.

A-2.2 Table 5 also shows the number of circuit-transfer operations performed, together with the duty performed, by each pair of contacts for each combination of switched current and recovery voltage during a number of cycles of operation corresponding to N tap-change operations.

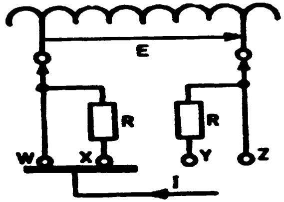
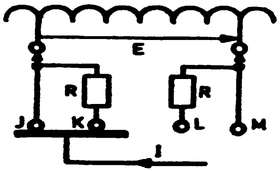
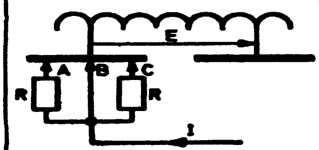
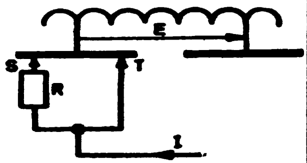
A-2.3 In the expressions for current and voltage in Table 5, the '+' and '−' signs indicate vectorial addition and subtraction, not algebraic. The duty on the contacts is consequently affected by the power-factor of the load on the transformer which controls the phase angle between the through-current I, and the step-voltage E. The effect of the load power-factor on the duty of the various contacts is shown in Table 6.

A-2.4 If the transition impedance is divided into two units, these are assumed to be of equal value, each equal to R.

A-2.5 The arrangements shown are by no means exhaustive; other possible arrangements exist and are used, such as the multiple resistor cycle which may be an extension of either the flag cycle or pennant cycle principle.

*The derivation of the designations 'flag cycle' and 'pennant cycle' arises from the appearance of the vector diagrams showing the change in output voltage of the transformer in moving from one tapping to the adjacent one. In the 'flag cycle' the change of voltage comprises four steps, while in the 'pennant cycle' only two steps occur (*see* Fig. 1 to 3).

TABLE 5 DUTY ON MAIN AND TRANSITION CONTACTS
(Clauses 8.6, 8.6.1.3, A-2.1, A-2.2 and A-2.3)

Type of Switch	Operating Cycle	Diagram of Connections	Contact Operating Order	Main Contact Duty: Contact	Main Contact Duty: Switched Current	Main Contact Duty: Recovery Voltage	Main Contact Duty: No. of Operations	Transition Contact Duty: Contact	Transition Contact Duty: Switched Current	Transition Contact Duty: Recovery Voltage	Transition Contact Duty: No. of Operations
Diverter switch	Flag cycle		*W* breaks *Y* makes *X* breaks *Z* makes	*W*	I	RI	$N/2$	*X*	$\frac{1}{2}(E/R+I)$ $\frac{1}{2}(E/R-I)$	$E+RI$ $E-RI$	$N/4$ $N/4$
				Z	I	RI	$N/2$	*Y*	$\frac{1}{2}(E/R+I)$ $\frac{1}{2}(E/R-I)$	$E+RI$ $E-RI$	$N/4$ $N/4$
	Symmetrical pennant cycle		*L* makes *J* breaks *M* makes *K* breaks	*J*	$E/R+I$ $E/R-I$	$\frac{1}{2}(E+RI)$ $\frac{1}{2}(E-RI)$	$N/4$ $N/4$	*K*	E/R	E	$N/2$
				M	$E/R+I$ $E/R-I$	$\frac{1}{2}(E+RI)$ $\frac{1}{2}(E-RI)$	$N/4$ $N/4$	*L*	E/R	E	$N/2$
Selector switch	Flag cycle		*C* breaks *B* breaks *C* makes *A* breaks *B* makes *A* makes	*B*	I	RI	N	*A*	$\frac{1}{2}(E/R+I)$	$E+RI$	$N/2$
								C	$\frac{1}{2}(E/R-I)$	$E-RI$	$N/2$
	Asymmetrical pennant cycle		*T* breaks *T* makes *S* breaks *S* makes	*T*	I	RI	$N/2$	*S*	E/R	E	$N/2$
					$(E/R-I)$	$(E-RI)$	$N/2$		O	O	$N/2$

NOTE 1 — Reversed load direction only affects contact *T* where the through-current and circulating current shall then add.
NOTE 2 — Other circuits involving multiple resistors are not included, as they are extensions of the above basic circuits.
NOTE 3 — For purposes of clarity, the diagrams of connections and contact operating order are given for one direction of movement of the switch. The expressions for contact duty and number of operations, however, take into account the movement of the switch in both directions.

TABLE 6 EFFECT OF LOAD POWER FACTOR ON CIRCUIT-BREAKING DUTY

(*Clause* A-2.3)

TYPE OF SWITCH	OPERATING CYCLE	MAIN CONTACTS		TRANSITION CONTACTS	
		Contact	Effect of Load Power Factor	Contact	Effect of Load Power Factor
Diverter switch	Flag cycle	*W* and *Z*	None	*X* and *Y*	Maximum duty at power factor = 1·0
	Symmetrical pennant cycle	*J* and *M*	Maximum duty at power factor = 1·0	*K* and *L*	None
Selector switch	Flag cycle	*B*	None	*A* and *C*	Maximum duty at power factor = 1·0
	Asymmetrical pennant cycle	*T*	None for $\frac{N}{2}$ operations Maximum duty at power factor = 0 for $\frac{N}{2}$ operations	*S*	None

NOTE — Tap-changers employing the asymmetrical pennant cycle are normally used with load current flow in one direction only.

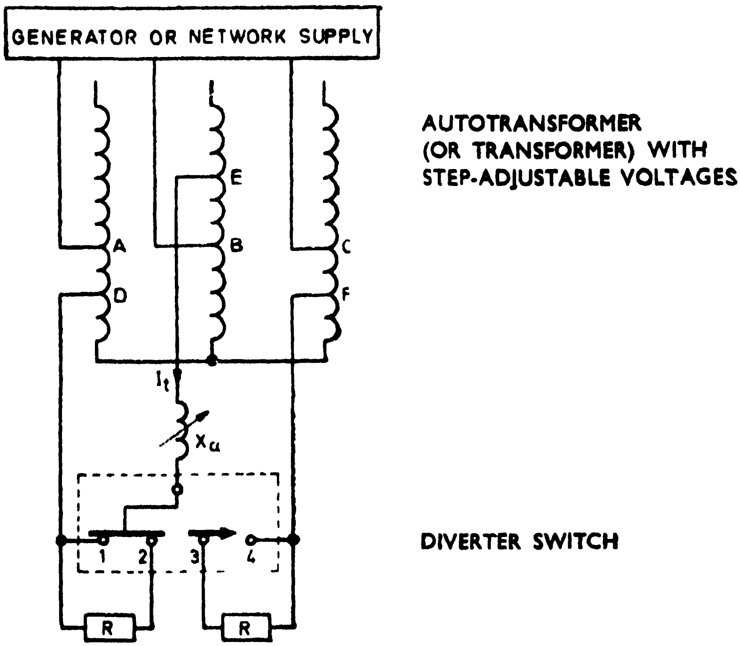
APPENDIX B

(*Clause* 8.6.3)

SIMULATED CIRCUITS FOR TESTS

B-1. Two proven simulated test circuits are shown in Fig. 4 and 5, Fig. 4 being a transformer method and Fig. 5 a resistance method.

These figures are given for information only and the use of different circuits is not excluded.



1, 4 = Mains contacts

2, 3 = Transition contacts

R = Transition resistor

X_a = Adjustable reactor

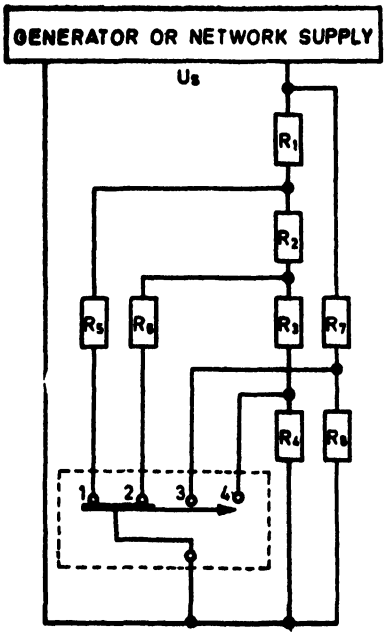
U_{AB} = $U_{BC} = U_{AC}$ = Three-phase supply voltage

I_t = Test current, to be adjusted by means of U_{ED} and X_a

U_{DF} = Step-voltage relevant to I_t

NOTE — In order to meet the requirements under **8.6.1** and **8.6.2** and to take into account the reactances of the circuit and supply, the current and voltage values occurring on the four contacts shall be controlled and when necessary suitably adjusted, for example by means of variations of the U_{FD}, X_a and R values and/or of the mutual phase of the voltage vectors.

FIG. 4 TRANSFORMER METHOD



POWER DIVIDER

1, 4 = main contacts
2, 3 = transition contacts
U_s = single phase supply voltage
$R_1, \ldots, R_8$ = ohmic resistors forming the power divider

DIVERTER SWITCH

NOTE — The calculated current and voltage values occurring in the whole tap-change operation on the four contacts shall be used to calculate the power divider. In the case under consideration (flag cycle on a 4-contacts diverter switch) the formulae for the most onerous conditions, are:

$$R_1 = \frac{U_s(U_s - U_1)}{I_4(U_s - U_4) + U_3 I_3};$$

$$R_2 = \frac{U_s(U_1 - U_2)}{I_4(U_s - U_4) + U_3 I_3} + \frac{U_s}{I_4(U_s - U_4)} \; \frac{U_2 I_2 (U_s - U_2)}{I_4(U_s - U_4) + U_3 I_3};$$

$$R_3 = \frac{U_3}{I_4} \cdot \frac{U_3 - U_4}{U_s - U_4};$$

$$R_4 = \frac{U_3}{I_4} \cdot \frac{U_4}{U_s - U_4};$$

$$R_5 = \frac{U_1}{I_1} - \frac{U_1(U_s - U_1)}{I_4(U_s - U_4) + U_3 I_3};$$

$$R_6 = \frac{U_2}{I_2} - \frac{U_2(U_s - U_2)}{I_4(U_s - U_4)};$$

$$R_7 = \frac{U_s}{I_3}; \text{ and}$$

$$R_8 = \frac{U_3}{I_3} \cdot \frac{U_s}{U_s - U_3}$$

where

I_1, I_2 = switched current rms values of contacts 1 and 2
U_1, U_2 = recovery voltage rms values of contacts 1 and 2
U_3, U_4 = applied voltage rms values of contacts 3 and 4
I_3, I_4 = making current rms values of contacts 3 and 4

In order to meet the requirements under 8.6.1 and 8.6.2 and to take into account the impedance of the supply, the current and voltage values occurring on the four contacts shall be controlled and when necessary adjusted by means of small variations of the R_1 ohmic value.

FIG. 5 RESISTANCE METHOD

APPENDIX C

(*Clause* 8.8)

METHOD OF DETERMINING THE EQUIVALENT TEMPERATURE OF THE TRANSITION RESISTOR USING POWER PULSE CURRENTS

C-1. Set up the resistor in a tap-changer or in a thermally equivalent situation, suitable arrangements being made to measure the temperature of the resistance material. The thermocouples or thermometers for measuring the temperature of the cooling medium should be positioned not less than 25 mm below the lowest point of the resistance material.

C-2. Measure and record the temperatures of the resistance material and of the cooling medium at the start of the test.

C-3. The test shall be performed with rms current I_p, the value of which is obtained from:

$$I_p = \frac{1}{\sqrt{k}} \sqrt{\frac{\sum_{i=1}^{n} (I_i^2 \cdot t_i)}{\sum_{i=1}^{n} e_i \, t_i}}$$

where

I_i = the current values;

t_i = the time during which the current I_i is flowing, both quantities taken as the mean value from the 100 oscillograms recorded at the service duty test according to **8.6.1.1** or if relevant to **8.6.1.2**(b); and

k = a coefficient chosen to suit the testing requirements of the resistor, the value adopted to be between 5 and 10 bearing in mind that the heating phenomenon shall remain adiabatic.

The resistor shall be subjected to the above current for a number of times corresponding to one half of one cycle of operations. The current application time shall be determined from:

$$t_p = k. \sum_{i=1}^{n} t_i$$

C-4. The rest period, during which current does not flow through the resistor shall be equal to the minimum time interval that can occur between two consecutive operations of the tap-changer.

C-5. To determine the peak temperature, extrapolation of recorded values may be necessary.

BUREAU OF INDIAN STANDARDS

Headquarters:
Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002
Telephones: 323 0131, 323 3375, 323 9402
Fax : 91 11 3234062, 91 11 3239399, 91 11 3239382

Telegrams : Manaksanstha
(Common to all Offices)

	Telephone
***Central Laboratory*:**	
Plot No. 20/9, Site IV, Sahibabad Industrial Area, Sahibabad 201010	8-77 00 32
Regional Offices:	
Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002	323 76 17
*Eastern : 1/14 CIT Scheme VII M, V.I.P. Road, Maniktola, CALCUTTA 700054	337 86 62
Northern : SCO 335-336, Sector 34-A, CHANDIGARH 160022	60 38 43
Southern : C.I.T. Campus, IV Cross Road, CHENNAI 600113	235 23 15
†Western : Manakalaya, E9, Behind Marol Telephone Exchange, Andheri (East), MUMBAI 400093	832 92 95
Branch Offices::	
'Pushpak', Nurmohamed Shaikh Marg, Khanpur, AHMEDABAD 380001	550 13 48
‡Peenya Industrial Area, 1st Stage, Bangalore-Tumkur Road, BANGALORE 560058	839 49 55
Gangotri Complex, 5th Floor, Bhadbhada Road, T.T. Nagar, BHOPAL 462003	55 40 21
Plot No. 62-63, Unit VI, Ganga Nagar, BHUBANESHWAR 751001	40 36 27
Kalaikathir Buildings, 670 Avinashi Road, COIMBATORE 641037	21 01 41
Plot No. 43, Sector 16 A, Mathura Road, FARIDABAD 121001	8-28 88 01
Savitri Complex, 116 G.T. Road, GHAZIABAD 201001	8-71 19 96
53/5 Ward No.29, R.G. Barua Road, 5th By-lane, GUWAHATI 781003	54 11 37
5-8-56C, L.N. Gupta Marg, Nampally Station Road, HYDERABAD 500001	20 10 83
E-52, Chitaranjan Marg, C-Scheme, JAIPUR 302001	37 29 25
117/418 B, Sarvodaya Nagar, KANPUR 208005	21 68 76
Seth Bhawan, 2nd Floor, Behind Leela Cinema, Naval Kishore Road, LUCKNOW 226001	23 89 23
NIT BUilding, Second Floor, Gokulpat Market, NAGPUR 440010	52 51 71
Patliputra Industrial Estate, PATNA 800013	26 23 05
Institution of Engineers (India) Building 1332 Shivaji Nagar, PUNE 411005	32 36 35
T.C. No. 14/1421, University P. O. Palayam, THIRUVANANTHAPURAM 695034	6 21 17

*Sales Office is at 5 Chowringhee Approach, P.O. Princep Street, CALCUTTA 700072	27 10 85
†Sales Office is at Novelty Chambers, Grant Road, MUMBAI 400007	309 65 28
‡Sales Office is at 'F' Block, Unity Building, Narashimaraja Square, BANGALORE 560002	222 39 71

Printed at Printograph, New Delhi, Ph : 5726847